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Goldstein et al.

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(54) ALTERING EVENT LIFETIMES

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G06F 9/54 (2006.01)
G06F 17/30 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 9/542*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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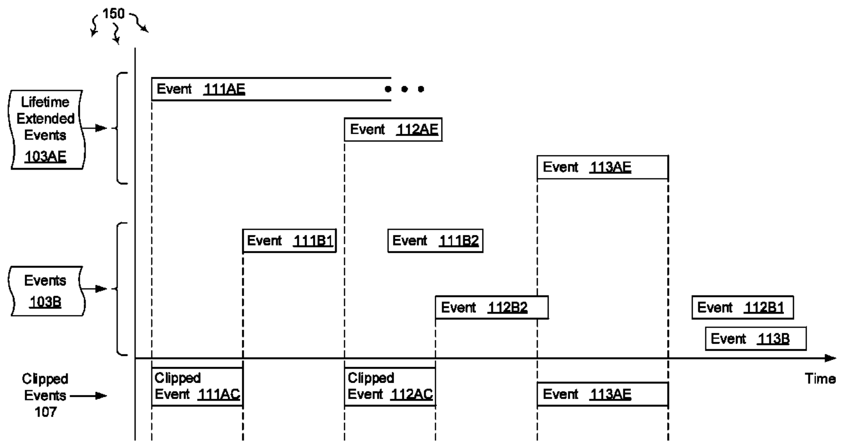
(57) ABSTRACT

The present invention extends to methods, systems, and computer program products for altering event lifetimes. Embodiments of the invention include using operators in an event-processing framework (algebra) to shorten (or "clip") the duration of events. An operator can receive a primary event stream, a clip event stream, and condition as parameters. The operator clips the lifetime of an event in the primary stream to the next event in the clip stream that fulfills the condition. Altering event lifetimes can be used to facilitate cleaning event stream state, converting point events to a continuous signal, and creating and annotating session events.

16 Claims, 9 Drawing Sheets



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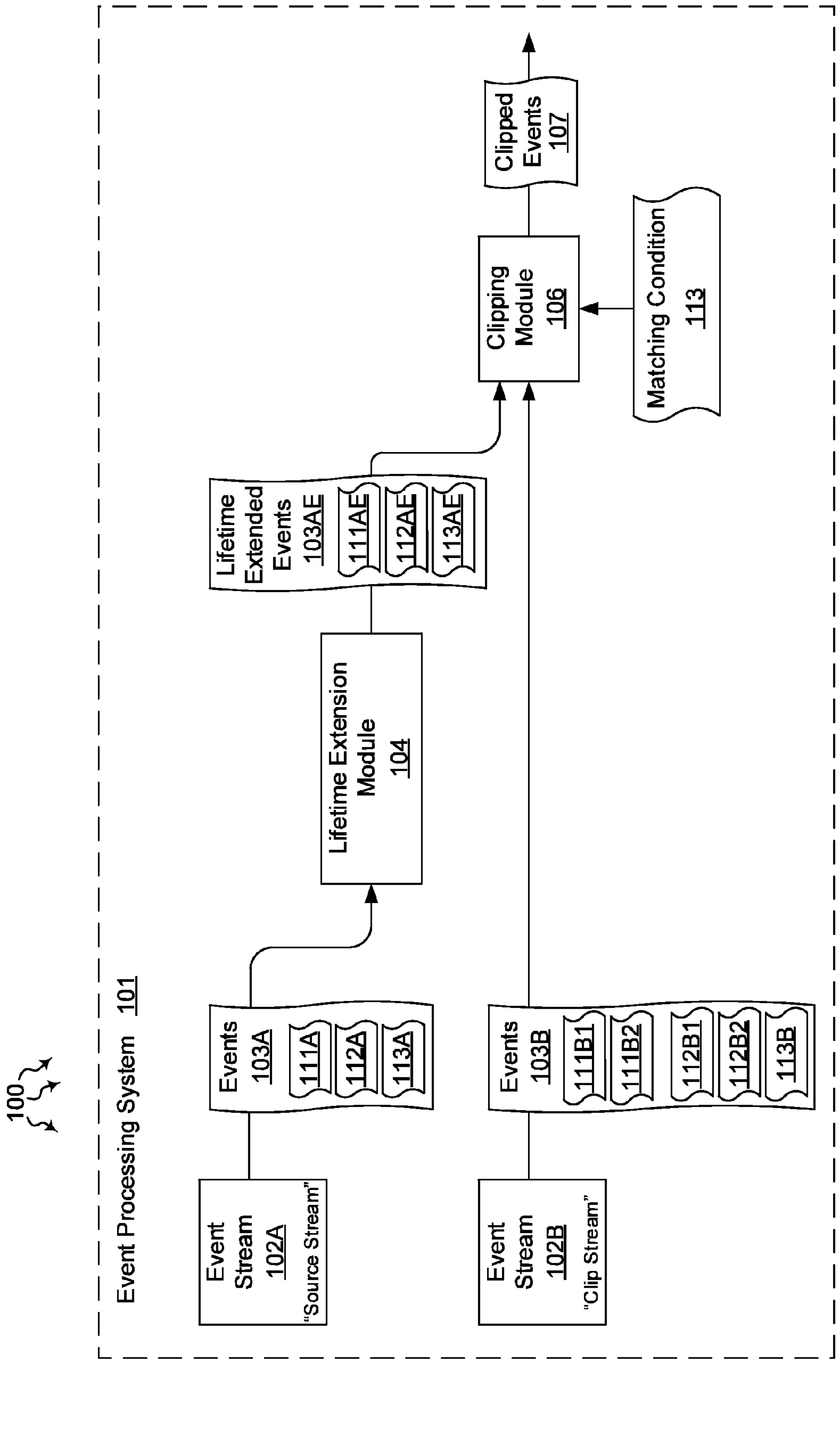

100
Event Processing System 101
Event Stream 102A "Source Stream"
Events 103A
111A
112A
113A
Lifetime Extension Module 104
Lifetime Extended Events 103AE
111AE
112AE
113AE
Event Stream 102B "Clip Stream"
Events 103B
111B1
111B2
112B1
112B2
113B
Clipping Module 106
Matching Condition 113
Clipped Events 107

Figure 1A

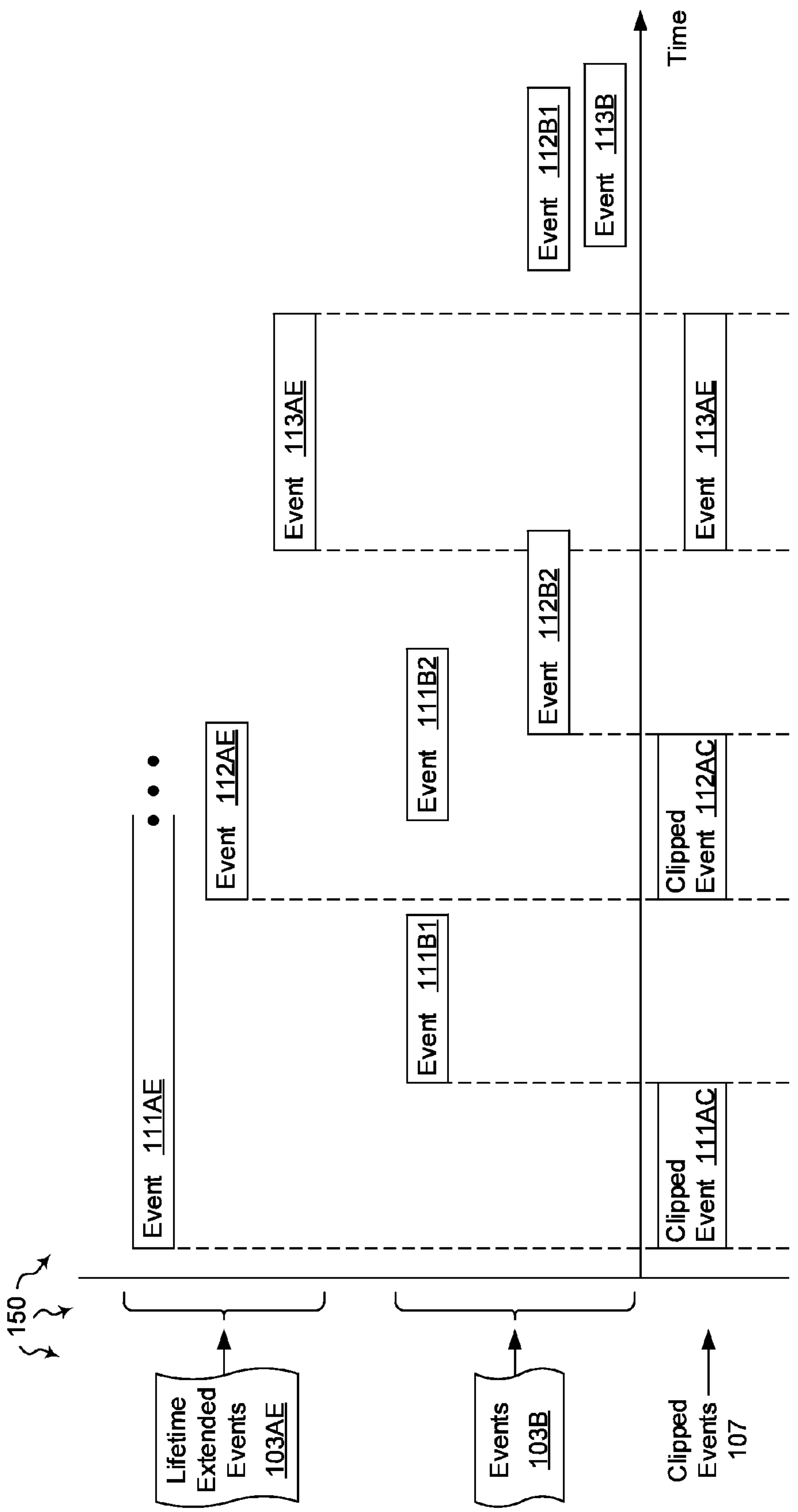

150
Lifetime Extended Events 103AE
Events 103B
Clipped Events 107
Event 111AE
Event 112AE
Event 113AE
Event 111B1
Event 111B2
Event 112B2
Event 112B1
Event 113B
Time
Clipped Event 111AC
Clipped Event 112AC
Event 113AE

Figure 1B

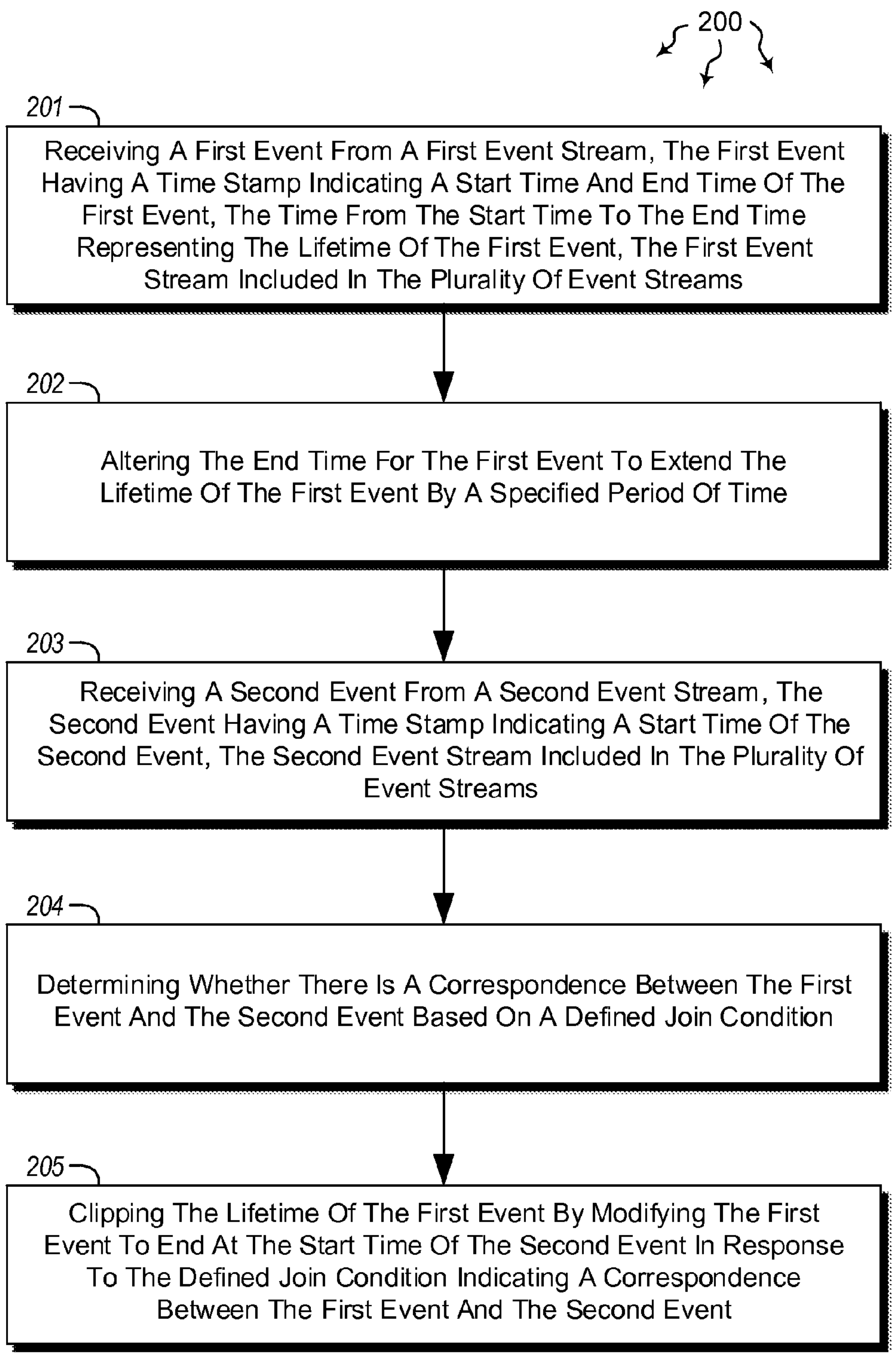

200
201
Receiving A First Event From A First Event Stream, The First Event Having A Time Stamp Indicating A Start Time And End Time Of The First Event, The Time From The Start Time To The End Time Representing The Lifetime Of The First Event, The First Event Stream Included In The Plurality Of Event Streams
202
Altering The End Time For The First Event To Extend The Lifetime Of The First Event By A Specified Period Of Time
203
Receiving A Second Event From A Second Event Stream, The Second Event Having A Time Stamp Indicating A Start Time Of The Second Event, The Second Event Stream Included In The Plurality Of Event Streams
204
Determining Whether There Is A Correspondence Between The First Event And The Second Event Based On A Defined Join Condition
205
Clipping The Lifetime Of The First Event By Modifying The First Event To End At The Start Time Of The Second Event In Response To The Defined Join Condition Indicating A Correspondence Between The First Event And The Second Event

Figure 2

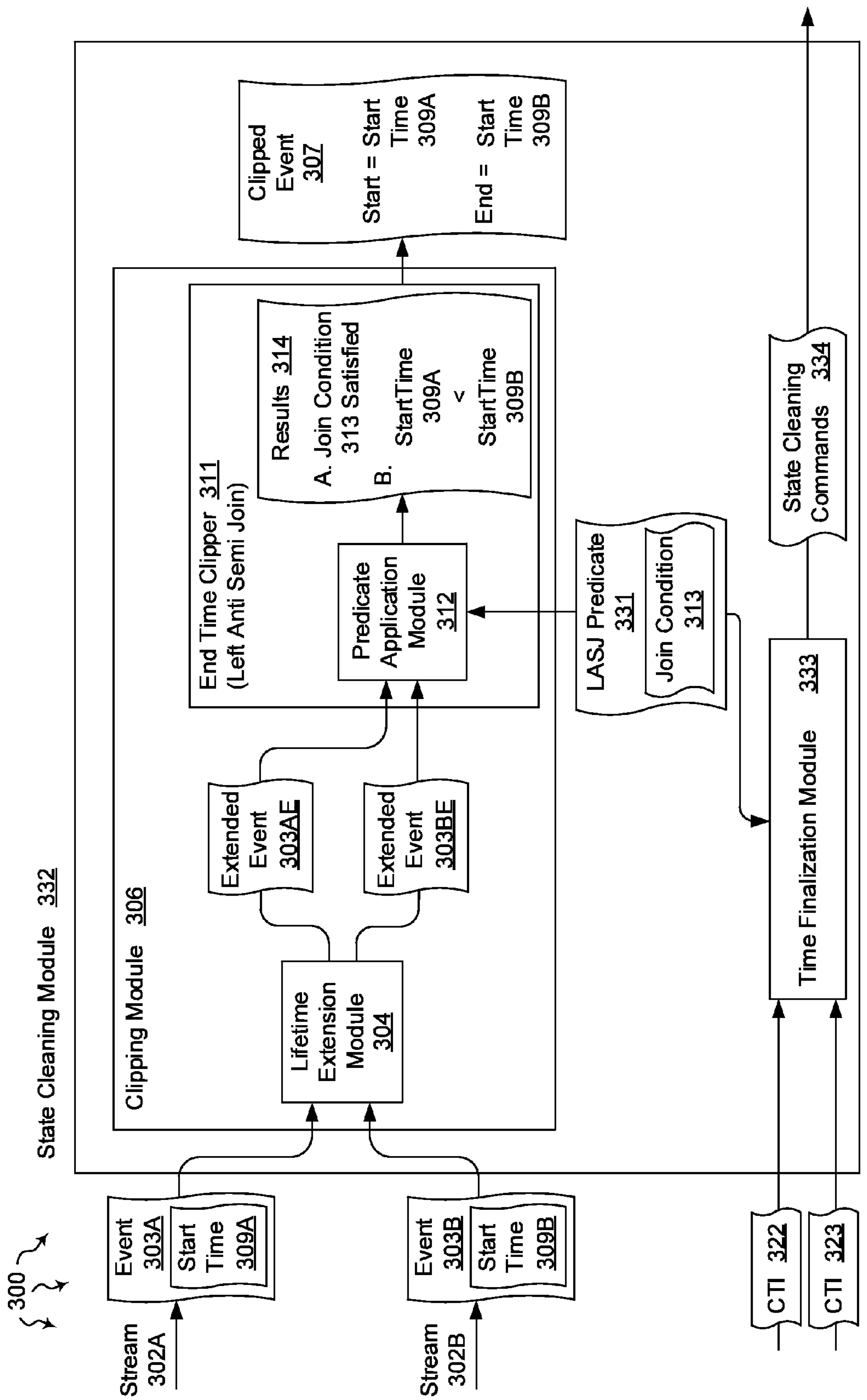

300
Stream 302A
Event 303A
Start Time 309A
Stream 302B
Event 303B
Start Time 309B
CTI 322
CTI 323
State Cleaning Module 332
Clipping Module 306
Lifetime Extension Module 304
Extended Event 303AE
Extended Event 303BE
End Time Clipper 311 (Left Anti Semi Join)
Predicate Application Module 312
Results 314
A. Join Condition 313 Satisfied
B. StartTime 309A < StartTime 309B
Clipped Event 307
Start = Start Time 309A
End = Start Time 309B
LASJ Predicate 331
Join Condition 313
Time Finalization Module 333
State Cleaning Commands 334

Figure 3

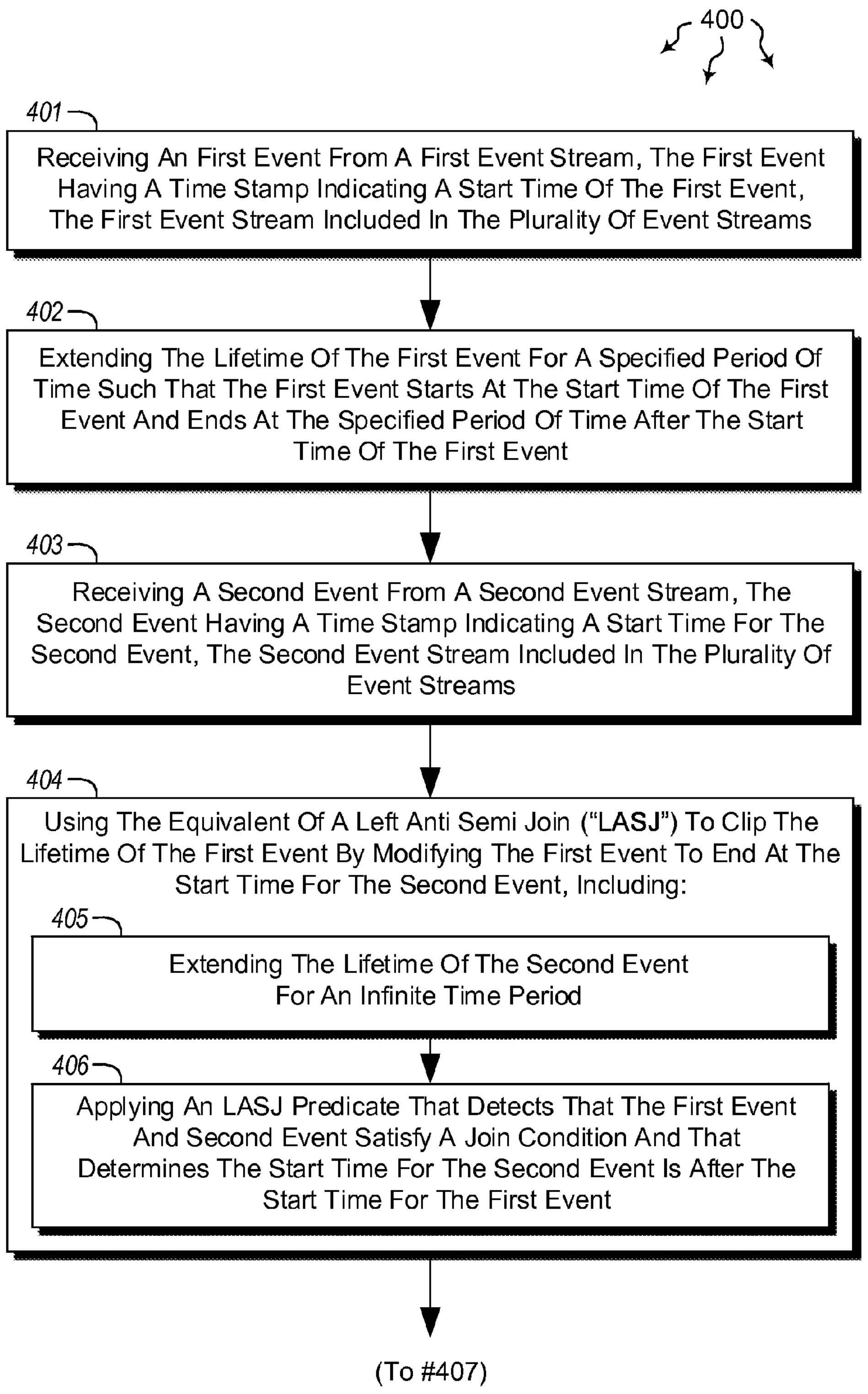

400
401
Receiving An First Event From A First Event Stream, The First Event Having A Time Stamp Indicating A Start Time Of The First Event, The First Event Stream Included In The Plurality Of Event Streams
402
Extending The Lifetime Of The First Event For A Specified Period Of Time Such That The First Event Starts At The Start Time Of The First Event And Ends At The Specified Period Of Time After The Start Time Of The First Event
403
Receiving A Second Event From A Second Event Stream, The Second Event Having A Time Stamp Indicating A Start Time For The Second Event, The Second Event Stream Included In The Plurality Of Event Streams
404
Using The Equivalent Of A Left Anti Semi Join ("LASJ") To Clip The Lifetime Of The First Event By Modifying The First Event To End At The Start Time For The Second Event, Including:
405
Extending The Lifetime Of The Second Event For An Infinite Time Period
406
Applying An LASJ Predicate That Detects That The First Event And Second Event Satisfy A Join Condition And That Determines The Start Time For The Second Event Is After The Start Time For The First Event
(To #407)

Figure 4

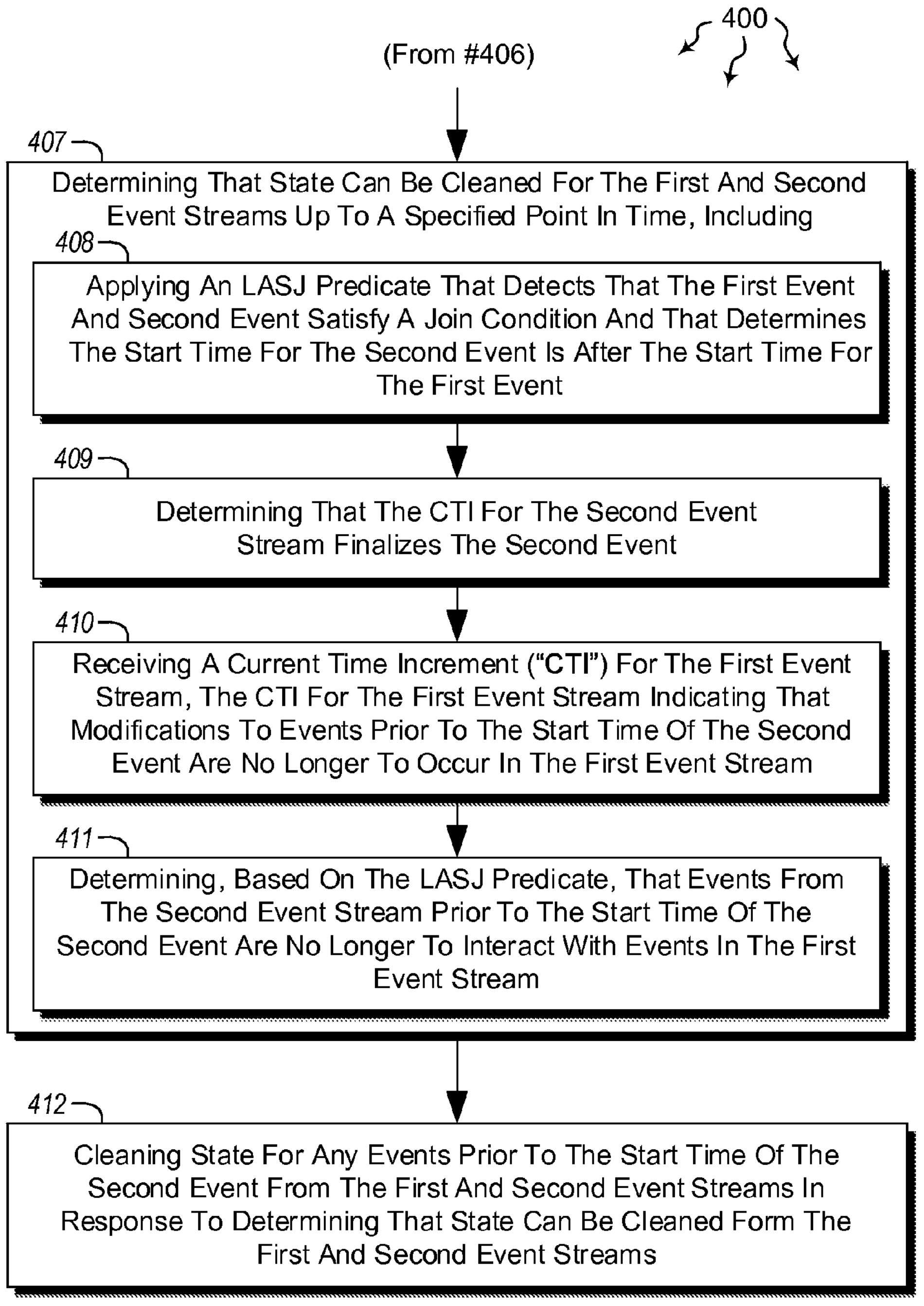
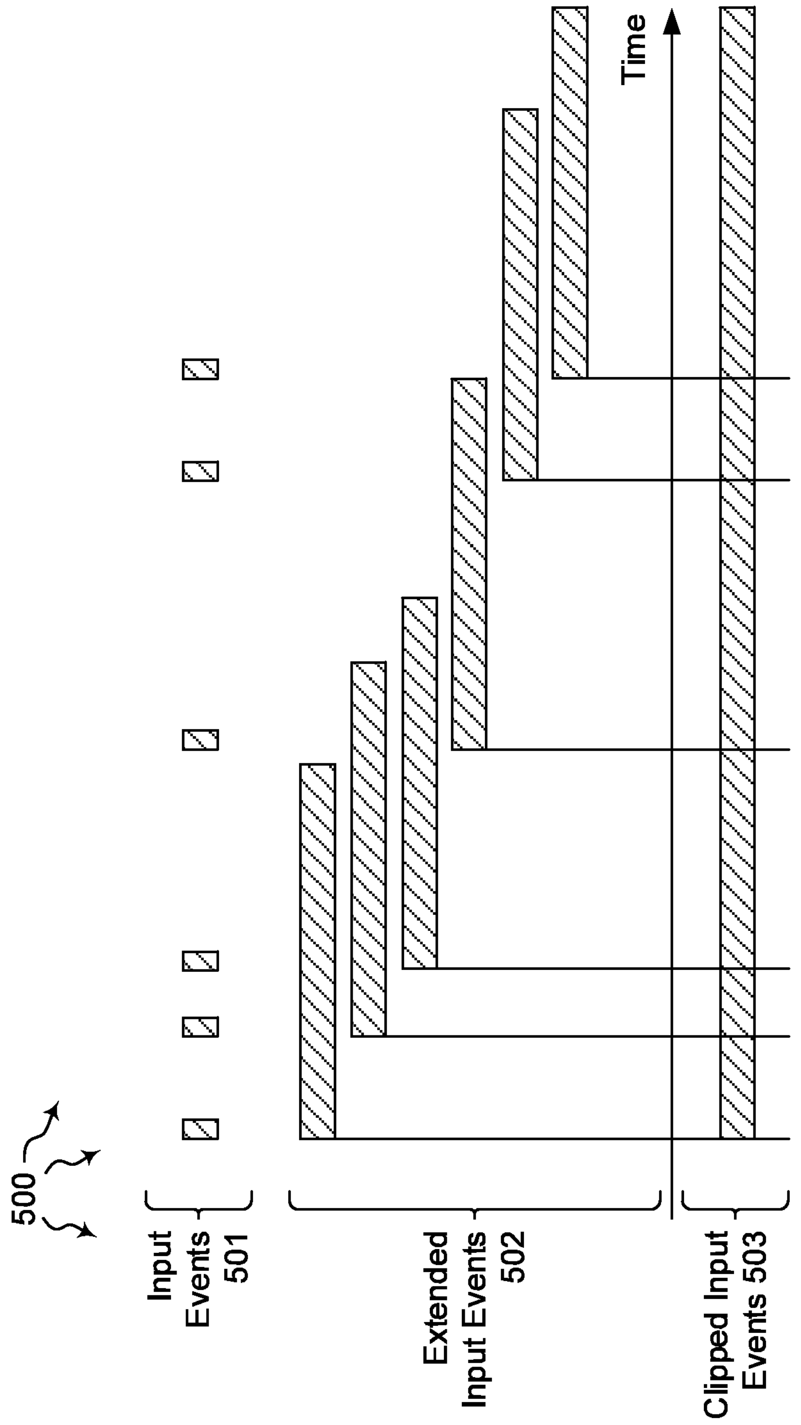

400
(From #406)
407
Determining That State Can Be Cleaned For The First And Second Event Streams Up To A Specified Point In Time, Including
408
Applying An LASJ Predicate That Detects That The First Event And Second Event Satisfy A Join Condition And That Determines The Start Time For The Second Event Is After The Start Time For The First Event
409
Determining That The CTI For The Second Event Stream Finalizes The Second Event
410
Receiving A Current Time Increment ("CTI") For The First Event Stream, The CTI For The First Event Stream Indicating That Modifications To Events Prior To The Start Time Of The Second Event Are No Longer To Occur In The First Event Stream
411
Determining, Based On The LASJ Predicate, That Events From The Second Event Stream Prior To The Start Time Of The Second Event Are No Longer To Interact With Events In The First Event Stream
412
Cleaning State For Any Events Prior To The Start Time Of The Second Event From The First And Second Event Streams In Response To Determining That State Can Be Cleaned Form The First And Second Event Streams

Figure 4
(Continued)



500
Input Events 501
Extended Input Events 502
Clipped Input Events 503
Time

Figure 5

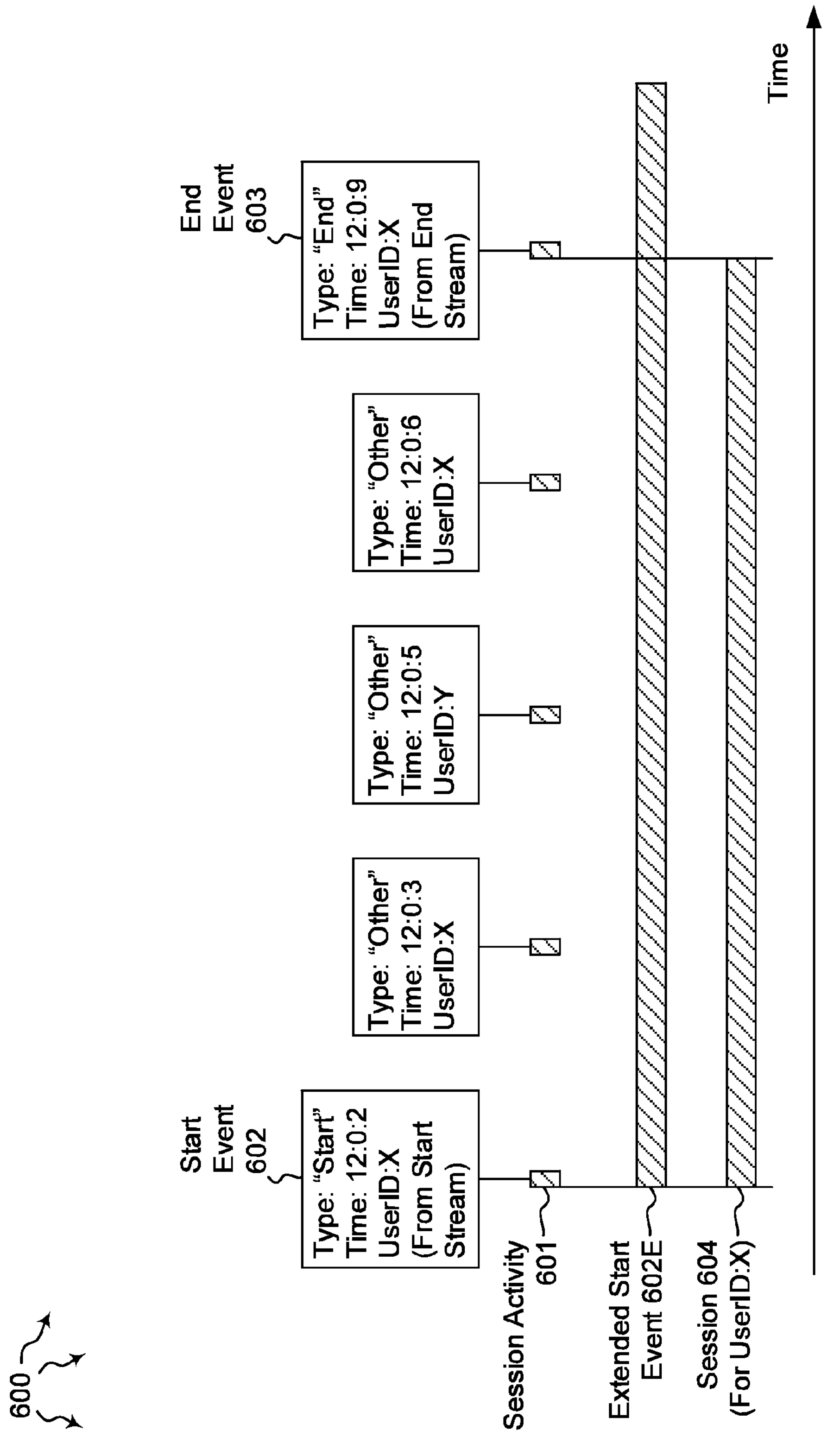

600
Start Event 602
Type: "Start"
Time: 12:0:2
UserID:X
(From Start Stream)
Type: "Other"
Time: 12:0:3
UserID:X
Type: "Other"
Time: 12:0:5
UserID:Y
Type: "Other"
Time: 12:0:6
UserID:X
End Event 603
Type: "End"
Time: 12:0:9
UserID:X
(From End Stream)
Session Activity 601
Extended Start Event 602E
Session 604 (For UserID:X)
Time

Figure 6A

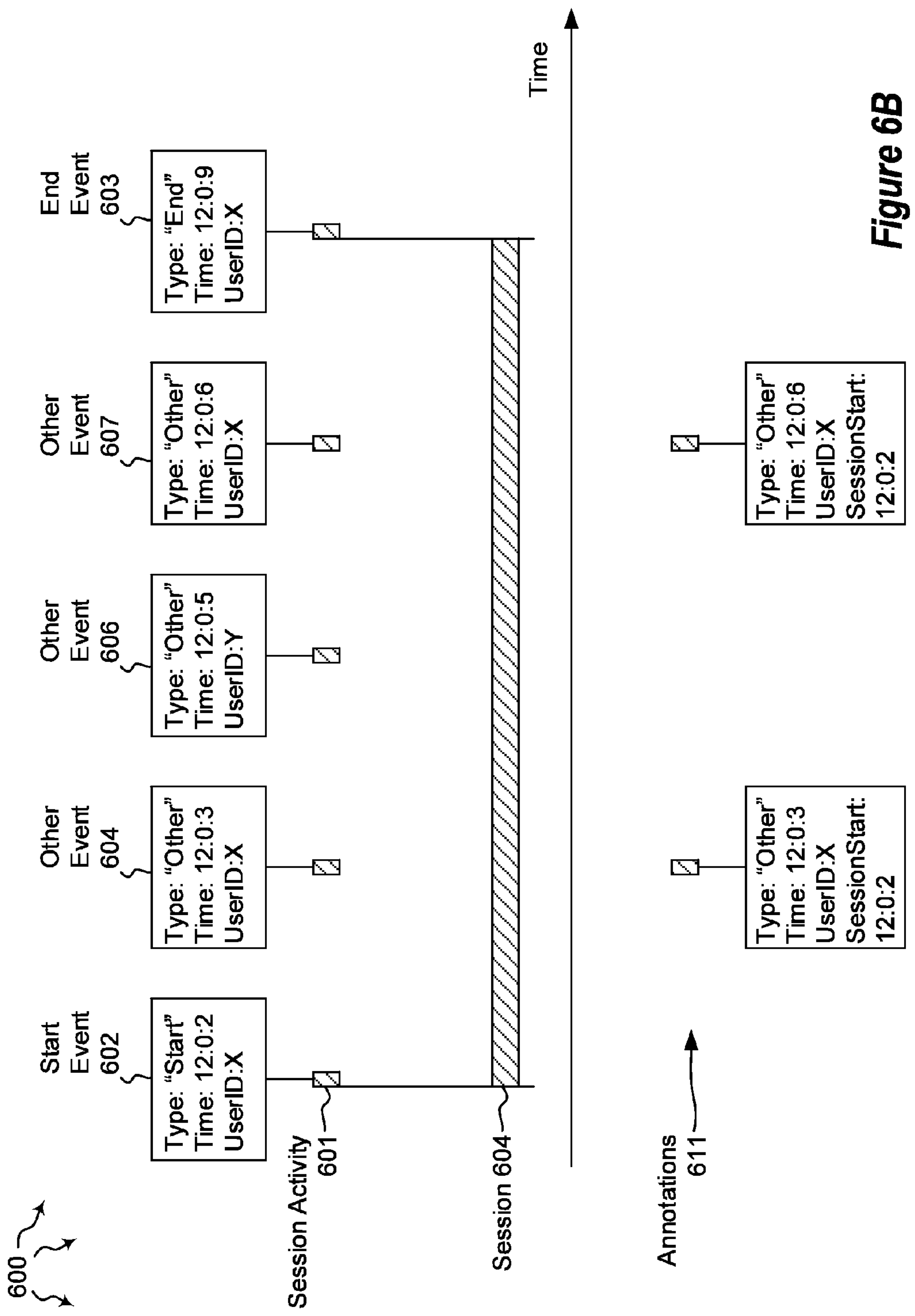

600
Session Activity 601
Session 604
Annotations 611
Time
Start Event 602
Type: "Start"
Time: 12:0:2
UserID:X
Other Event 604
Type: "Other"
Time: 12:0:3
UserID:X
Other Event 606
Type: "Other"
Time: 12:0:5
UserID:Y
Other Event 607
Type: "Other"
Time: 12:0:6
UserID:X
End Event 603
Type: "End"
Time: 12:0:9
UserID:X
Type: "Other"
Time: 12:0:3
UserID:X
SessionStart:
12:0:2
Type: "Other"
Time: 12:0:6
UserID:X
SessionStart:
12:0:2

Figure 6B

ALTERING EVENT LIFETIMES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of and claims benefit of U.S. patent application Ser. No. 12/893,775, entitled "ALTERING EVENT LIFETIMES," which was filed on Sep. 29, 2010, U.S. Pat. No. 8,752,072 and which is incorporated herein by reference in its entirety.

BACKGROUND

1. Background and Relevant Art

Computer systems and related technology affect many aspects of society. Indeed, the computer system's ability to process information has transformed the way we live and work. Computer systems now commonly perform a host of tasks (e.g., word processing, scheduling, accounting, etc.) that prior to the advent of the computer system were performed manually. More recently, computer systems have been coupled to one another and to other electronic devices to form both wired and wireless computer networks over which the computer systems and other electronic devices can transfer electronic data. Accordingly, the performance of many computing tasks are distributed across a number of different computer systems and/or a number of different computing environments.

Some distributed systems are event processing systems that process events and take actions based on events. Events typically represent a change in state at some other system, such as, for example, the starting or ending a session, selling an item, open or closing a file, etc. Some event processing systems process multiple streams of event data with the goal of identifying meaningful events within those streams. To identify meaningful events, event processing systems can employ techniques such as detection of complex patterns of many events, event correlation and abstraction, event hierarchies, and relationships between events (e.g., causality, membership, and timing, and event-driven processes).

Within event streams, events typically have a lifetime, determined by a start time and end time. Identifying interesting events, and more specifically matching events from different streams to one another, may require the lifetime of the events to overlap. However, it is not uncommon for an event in one stream to end before a matching event in another stream starts. Further, in some event processing systems, events can be point events where the start time for the event and the end time for the event are the same. Since points events essentially start and end at the same time matching point events from different streams within one another can be difficult.

BRIEF SUMMARY

The present invention extends to methods, systems, and computer program products for altering event lifetimes. In some embodiments, the lifetime of an event in one event stream is adjusted based on an event in another event stream. A first event is received from a first event stream. The first event has a time stamp indicating a start time and end time of the first event. The time from the start time to the end time represents the lifetime of the first event. The first event stream is included in a plurality of event streams. The end time for the first event is altered to extend the lifetime of the first event by a specified period of time.

A second event is received from a second event stream. The second event has a time stamp indicating a start time of the second event. The second event stream is included in the plurality of event stream. It is determined whether there is a correspondence between the first event and the second event based on a defined join condition. The lifetime of the first event is clipped by modifying the first event to end at the start time of the second event. The lifetime of the first event is clipped in response to the defined join condition indicating a correspondence between the first event and the second event.

In other embodiments, state is cleaned from event streams. A first event is received from a first event stream. The first event has a time stamp indicating a start time of the first event. The first event stream is included in a plurality of event streams. The lifetime of the first event is extended for a specified period of time such that the first event starts at the start time of the first event and ends at the specified period of time after the start time of the first event. A second event is received from a second event stream. The second event has a time stamp indicating a start time for the second event. The second event stream is included in the plurality of event streams.

The equivalent of a Left Anti Semi Join ("LASJ") is used to clip the lifetime of the first event by modifying the first event to end at the start time for the second event. Using the equivalent of a LASJ includes extending the lifetime of the second event for an infinite time period. Using the equivalent of a LASJ includes also includes applying an LASJ predicate that detects that the first event and second event satisfy a join condition and that determines the start time for the second event is after the start time for the first event.

It is determined that state can be cleaned for the first and second event streams up to a specified point in time. Determining that state can be cleaned includes receiving a current time increment ("CTI") for the second event stream. The CTI for the second event stream indicates that modifications to events prior to the start time of the second event are no longer to occur in the second event stream. It is determined that the CTI for the second event stream finalizes the second event.

Determining that state can be cleaned includes receiving a current time increment ("CTI") for the first event stream. The CTI for the first event stream indicates that modifications to events prior to the start time of the second event are no longer to occur in the first event stream. Determining that state can be cleaned includes determining, based on the LASJ predicate, that events from the second event stream prior to the start time of the second event are no longer to interact with events in the first event stream.

State for any events prior to the start time of the second event are cleaned from the first and second event streams in response to determining that state can be cleaned form the first and second event streams.

This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

Additional features and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by the practice of the invention. The features and advantages of the invention may be realized and obtained by means of the instruments and combinations particularly pointed out in the appended claims. These and other features of the present invention will become more fully apparent from the following

description and appended claims, or may be learned by the practice of the invention as set forth hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to describe the manner in which the above-recited and other advantages and features of the invention can be obtained, a more particular description of the invention briefly described above will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments of the invention and are not therefore to be considered to be limiting of its scope, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

FIG. **1**A illustrates an example computer architecture that facilitates altering event lifetimes.

FIG. **1**B illustrates a graph of clipped events having alerted lifetimes.

FIG. **2** illustrates a flow chart of an example method for altering event lifetimes.

FIG. **3** illustrates an example computer architecture that facilitates cleaning state for event streams.

FIG. **4** illustrates a flow chart of an example method for cleaning state for event streams.

FIG. **5** illustrates a graph of events representing point to signal conversion.

FIG. **6**A illustrates a graph of events representing creation of session events.

FIG. **6**B illustrates a graph of events representing annotating session events with other events.

DETAILED DESCRIPTION

The present invention extends to methods, systems, and computer program products for altering event lifetimes. In some embodiments, the lifetime of an event in one event stream is adjusted based on an event in another event stream. A first event is received from a first event stream. The first event has a time stamp indicating a start time and end time of the first event. The time from the start time to the end time represents the lifetime of the first event. The first event stream is included in a plurality of event streams. The end time for the first event is altered to extend the lifetime of the first event by a specified period of time.

A second event is received from a second event stream. The second event has a time stamp indicating a start time of the second event. The second event stream is included in the plurality of event stream. It is determined whether there is a correspondence between the first event and the second event based on a defined join condition. The lifetime of the first event is clipped by modifying the first event to end at the start time of the second event. The lifetime of the first event is clipped in response to the defined join condition indicating a correspondence between the first event and the second event.

In other embodiments, state is cleaned from event streams. A first event is received from a first event stream. The first event has a time stamp indicating a start time of the first event. The first event stream is included in a plurality of event streams. The lifetime of the first event is extended for a specified period of time such that the first event starts at the start time of the first event and ends at the specified period of time after the start time of the first event. A second event is received from a second event stream. The second event has a time stamp indicating a start time for the second event. The second event stream is included in the plurality of event streams.

The equivalent of a Left Anti Semi Join ("LASJ") is used to clip the lifetime of the first event by modifying the first event to end at the start time for the second event. Using the equivalent of a LASJ includes extending the lifetime of the second event for an infinite time period. Using the equivalent of a LASJ includes also includes applying an LASJ predicate that detects that the first event and second event satisfy a join condition and that determines the start time for the second event is after the start time for the first event.

It is determined that state can be cleaned for the first and second event streams up to a specified point in time. Determining that state can be cleaned includes receiving a current time increment ("CTI") for the second event stream. The CTI for the second event stream indicates that modifications to events prior to the start time of the second event are no longer to occur in the second event stream. It is determined that the CTI for the second event stream finalizes the second event.

Determining that state can be cleaned includes receiving a current time increment ("CTI") for the first event stream. The CTI for the first event stream indicates that modifications to events prior to the start time of the second event are no longer to occur in the first event stream. Determining that state can be cleaned includes determining, based on the LASJ predicate, that events from the second event stream prior to the start time of the second event are no longer to interact with events in the first event stream.

State for any events prior to the start time of the second event are cleaned from the first and second event streams in response to determining that state can be cleaned form the first and second event streams.

Embodiments of the present invention may comprise or utilize a special purpose or general-purpose computer including computer hardware, such as, for example, one or more processors and system memory, as discussed in greater detail below. Embodiments within the scope of the present invention also include physical and other computer-readable media for carrying or storing computer-executable instructions and/or data structures. Such computer-readable media can be any available media that can be accessed by a general purpose or special purpose computer system. Computer-readable media that store computer-executable instructions are physical storage media. Computer-readable media that carry computer-executable instructions are transmission media. Thus, by way of example, and not limitation, embodiments of the invention can comprise at least two distinctly different kinds of computer-readable media: computer storage media and transmission media.

Computer storage media includes RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store desired program code means in the form of computer-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer.

A "network" is defined as one or more data links that enable the transport of electronic data between computer systems and/or modules and/or other electronic devices. When information is transferred or provided over a network or another communications connection (either hardwired, wireless, or a combination of hardwired or wireless) to a computer, the computer properly views the connection as a transmission medium. Transmissions media can include a network and/or data links which can be used to carry or desired program code means in the form of computer-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer. Combinations of the above should also be included within the scope of computer-readable media.

Further, upon reaching various computer system components, program code means in the form of computer-executable instructions or data structures can be transferred automatically from transmission media to computer storage media (or vice versa). For example, computer-executable instructions or data structures received over a network or data link can be buffered in RAM within a network interface module (e.g., a "NIC"), and then eventually transferred to computer system RAM and/or to less volatile computer storage media at a computer system. Thus, it should be understood that computer storage media can be included in computer system components that also (or even primarily) utilize transmission media.

Computer-executable instructions comprise, for example, instructions and data which, when executed at a processor, cause a general purpose computer, special purpose computer, or special purpose processing device to perform a certain function or group of functions. The computer executable instructions may be, for example, binaries, intermediate format instructions such as assembly language, or even source code. Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the described features or acts described above. Rather, the described features and acts are disclosed as example forms of implementing the claims.

Those skilled in the art will appreciate that the invention may be practiced in network computing environments with many types of computer system configurations, including, personal computers, desktop computers, laptop computers, message processors, hand-held devices, multi-processor systems, microprocessor-based or programmable consumer electronics, network PCs, minicomputers, mainframe computers, mobile telephones, PDAs, pagers, routers, switches, and the like. The invention may also be practiced in distributed system environments where local and remote computer systems, which are linked (either by hardwired data links, wireless data links, or by a combination of hardwired and wireless data links) through a network, both perform tasks. In a distributed system environment, program modules may be located in both local and remote memory storage devices.

FIG. **1**A illustrates an example computer architecture **100** that facilitates altering event lifetimes. Referring to FIG. **1**A, computer architecture **100** includes event processing system **101**. Event processing system **101** further includes event stream **102**A, event stream **102**B, lifetime extension module **104**, and clipping module **106**. Each of the depicted components is connected to one another over (or is part of) a network, such as, for example, a Local Area Network ("LAN"), a Wide Area Network ("WAN"), and even the Internet. Accordingly, each of the depicted computer systems as well as any other connected computer systems and their components, can create message related data and exchange message related data (e.g., Internet Protocol ("IP") datagrams and other higher layer protocols that utilize IP datagrams, such as, Transmission Control Protocol ("TCP"), Hypertext Transfer Protocol ("HTTP"), Simple Mail Transfer Protocol ("SMTP"), etc.) over the network.

Event streams **102**A and **102**B can output events **103**A and **103**B (i.e., corresponding streams of events) respectively.

FIG. **2** illustrates a flow chart of an example method for altering event lifetimes. Method **200** will be described with respect to the components and data of computer architecture **100**.

Method **200** includes an act of receiving a first event from a first event stream, the first event having a time stamp indicating a start time and end time of the first event, the time from the start time to the end time representing the lifetime of the first event, the first event stream included in the plurality of event streams (act **201**). For example, event processing system **101** can receive events **103**A, including events **111**A, **112**A, and **113**A. Each of events **111**A, **112**A, and **113**A can have a time stamp indicating a start time and stop time. The time from the start time to the end time represents the lifetime of the events **111**A, **112**A, and **113**A respectively. Event stream **102**A can be one of a plurality of event streams in event processing system **101**.

Method **200** includes an act of altering the end time for the first event to extend the lifetime of the first event by a specified period of time (act **202**). For example, lifetime extension module **104** can extend the lifetime of events **111**A, **112**A, and **113**A. In some embodiments, lifetime extension module **104** implements an Alter Event Duration operator to extend the lifetime of an event by altering the end time for the event. The Alter Event Duration operator can extend the lifetime of an event by a selected finite amount of time (e.g., 30 seconds, 60 seconds, 10 minutes, etc.) or by an infinite amount of time. An Alter Event Duration operator can be of any of the following formats:

```
var extended = input.AlterEventDuration
(event => TimeSpan.FromSeconds(60));
var extended = input.AlterEventDuration
(event => TimeSpan.FromMinutes(10));
var extended = input.AlterEventDuration
(event => TimeSpan.Infinite( ));
```

Lifetime extension module **104** can output lifetime extended events **103**AE, including events **111**AE, **1112**AE, and **113**AE. Events **111**AE, **112**AE, and **113**AE have the same start times as events **111**A, **112**A, and **113**A and have had their lifetimes extended by altering the end times of events **111**A, **112**A, and **113**A. That is, events **111**AE, **1112**AE, and **113**AE and events **111**A, **112**A, and **113**A represent the same events but **111**AE, **1112**AE, and **113**AE end at a later time than events **111**A, **112**A, and **113**A respectively.

Lifetime extension module **104** can provide lifetime extended events **103**AE to clipping module **106**.

Method **200** includes an act of receiving a second event from a second event stream, the second event having a time stamp indicating a start time of the second event, the second event stream included in the plurality of event streams (act **203**). For example, event processing system **101** can receive events **103**A, including events **111**B1, **111**B2, **112**B1, **112**B2, and **113**B. Each of events **111**B1, **111**B2, **112**B1, **112**B2, and **113**B can have a time stamp indicating a start time (and potentially also a stop time). Event stream **102**B can be one of a plurality of event streams in event processing system **101**. Events **103**B can be provided to clipping module **106**.

Method **200** includes an act of determining whether there is a correspondence between the first event and the second event based on a defined join condition (act **204**). For example, clipping module **106** can determine whether there is a correspondence between events in lifetime extended events **103**AE and events in events **103**B (e.g., whether events correspond to the same session) based on matching condition **113**. Method **200** includes an act of clipping the lifetime of the first event by modifying the first event to end at the start time of the second event in response to the defined join condition indicating a correspondence between the first event and the second event (act **205**). For example, the lifetime of events in lifetime extended events **103**AE can be clipped by modifying the events in lifetime extended events **103**AE to end at the start time of events in events **103**B in response to matching condition **113** indicating a correspondence.

In some embodiments, a Clip Event Duration operator is used to adjust the lifetime of events with respect to other events. Generally, a Clip Event Duration operator can have three parameters: (i) a "source stream", (ii) a "clip stream", and (iii) a matching condition. For each event in the source stream, the lifetime of the event is truncated to the start time of the next (e.g., in terms of application time) matching event in the clip stream. The matching condition can be a Boolean expression of the payloads of source stream and clip stream. The matching condition can be configured with temporal restrictions such that events in the clip stream that are entirely after the source stream event are not a match. Thus, if the first otherwise matching event occurs entirely after the source stream event or does not exist at all, the source stream event can remain unchanged.

Clip Event Duration operator can be used to create session events, where the beginning and the end of a session is known and encoded as separate events, and can be used to convert a series of points into a continuous signal of intervals.

A Clip Event Duration operator can be of the format:

var result=sourcestream.ClipEventDuration(clipstream, joincondition);

More specifically, for creating a session event, a Clip Event Duration operator can be of the format:

var clipped=sourcestream.ClipEventDuration(clipstream, (e1, e2)=>e1.Id==e2.Id);

This example takes each event in sourcestream and shortens its lifetime by setting its end time to the start time of the next (in terms of application time) event in clipstream that has the same value of the field Id. If the lifetime of the respective event in stream1 was not long enough to overlap with the next event in stream2 or no matching event exists in stream2, then the event's lifetime remains unchanged.

Clipping module **106** can output clipped events **107**.

FIG. **1**B illustrates a graph **150** of clipped events **107** having altered lifetimes. Within graph **150**, events **111**AE, **112**AE, and **113**AE (from lifetime extended events **103**AE) and events **111B1**, **111B2**, **112B1**, **112B2**, and **113**B (from events **103**B) are presented. Clipped events **107** includes any events from lifetime extended events **103**AE that are clipped to the start time of an event in events **103**B

As depicted, the lifetime of event **111**AE has been extended infinitely (as represented by the ellipsis). Within events **103**B, event **111B1** is the first event (temporally) that matches event **111**AE. Thus, the end time for event **111**AE is clipped to the start time of event **111B1**. Clipped event **111**AC is the resulting clipped event. Event **111B2** is ignored because it occurs temporally after event **111B1**.

As depicted, the lifetime of event **112**AE has been extended for a finite period of time. Within events **103**B, event **112B2** is the first event (temporally) that matches event **112**AE. Thus, the end time for event **112**AE is clipped to the start time of event **111B2**. Clipped event **112**AC is the resulting clipped event. Event **112B1** is ignored because it occurs temporally after event **111B2**.

As depicted, the lifetime of event **113**AE has been extended for a finite period of time. Within events **103**B, event

113B is the first event (temporally) that matches event **113**AE. However, since event **113**B starts after event **113**AE otherwise ends, event **113**B is ignored and **113**AE is not clipped. Thus, event **113**AE is included unclipped within clipped events **107**.

One implementation of ClipEventDuration operator design includes using a Left Anti Semi Join ("LASJ") of the format:

LASJ (input 1, input 2, join predicate).

Generally, LASJ receives a first input (e.g., input 1), a second input (e.g., input 2) and an LASJ predicate (e.g., join predicate). LASJ is a logical operator that returns each row the first input (input 1) when there is no matching row in the second input (input 2). If no LASJ predicate exists each row is a matching row.

One example of achieving a join logically represented by an LASJ is:

```
SELECT * FROM T1 LEFT JOIN T2
ON T1.foreign_key = T2.key
WHERE T2.key IS NULL
```

FIG. **3** illustrates an example computer architecture **300** that facilitates cleaning state for event streams. Referring to FIG. **3**, computer architecture **200** includes state cleaning module **332**. State cleaning module **332** further includes clipping module **306** and time finalization module. Clipping module **306** further includes lifetime extension module **304** and end time clipper **311**. Each of the depicted components is connected to one another over (or is part of) a network, such as, for example, a Local Area Network ("LAN"), a Wide Area Network ("WAN"), and even the Internet. Accordingly, each of the depicted computer systems as well as any other connected computer systems and their components, can create message related data and exchange message related data (e.g., Internet Protocol ("IP") datagrams and other higher layer protocols that utilize IP datagrams, such as, Transmission Control Protocol ("TCP"), Hypertext Transfer Protocol ("HTTP"), Simple Mail Transfer Protocol ("SMTP"), etc.) over the network.

Streams **302**A and **302**B can be streaming events to state cleaning module **332**. Current time increments ("CTIs") can also be sent to state cleaning module **332**. A CTI indicates when events prior to the start time of a specified event are no longer to occur. For example, if an event has a start time of t=6 and a CTI of t=7 (or some later time) is received, then no events prior to the event (temporally) are to be received.

Time finalization module **333** is configured to determine when events are finalized (i.e., can no longer be changed or retracted) based on CTIs.

FIG. **4** illustrates a flow chart of an example method **400** for cleaning state for event streams. Method **400** will be described with respect to the components and data of computer architecture **300**.

Method **400** includes an act of receiving a first event from a first event stream, the first event having a time stamp indicating a start time of the first event, the first event stream included in the plurality of event streams (act **401**). For example, state cleaning module **332** can receive event **303**A having start time **309**A.

Method **400** includes an act of extending the lifetime of the first event for a specified period of time such that the first event starts at the start time of the first event and ends at the specified period of time after the start time of the first event (act **402**). For example, lifetime extension module **304** can generate extended event **303**AE from event **303**A. Event

303AE can extend the lifetime of event **303**A such that event **303**A starts at start time **309**A and ends a specified period (either finite or infinite) of time after start time **309**A.

Method **400** includes an act of receiving a second event from a second event stream, the second event having a time stamp indicating a start time for the second event, the second event stream included in the plurality of event streams (act **403**). For example, state cleaning module **332** can receive event **303**B having start time **309**B.

Method **400** includes an act of using the equivalent of a Left Anti Semi Join ("LASJ") to clip the lifetime of the first event by modifying the first event to end at the start time for the second event (act **404**). For example, end time clipper **311** can use the equivalent of an LASJ to clip the lifetime of event **303**A to end at start time **309**B.

Method **400** includes an act of extending the lifetime of the second event for an infinite time period (act **405**). For example, lifetime extension module **304** can generate extended event **303**BE from event **303**B. Event **303**BE can extend the lifetime of event **303**B such that event **303**B starts at start time **309**B and ends a specified period (either finite or infinite) of time after start time **309**B.

Method **400** includes an act of applying an LASJ predicate that detects that the first event and second event satisfy a join condition and that determines the start time for the second event is after the start time for the first event (act **406**). For example, predicate application module **312** can apply LASJ predicate **331** to extended events **303**AE and **303**BE. LASJ predicate **331** can detect that extended events **303**AE and **303**BE satisfy join condition **313** and that the start time for extended event **303**BE is after the start time for extended event **303**AE

In some embodiments, the LASJ operator is represent as:

LASJ(S1, AlterLifetime(S2, F_{delta}=Infinity), f AND S1.Vs<S2.Vs)

The first input is S1 (e.g., event **303**AE), the second input is AlterLifetime(S2, F_{delta}=Infinity)) (where S2 can be event **303**BE), and the LASJ predicate is a join condition f and temporal constraint S1.Vs<S2.Vs. For the LASJ to be applied, the join condition f and temporal constraint are to be satisfied S1.Vs<S2.Vs. The join condition f can, for example, defines that two events (e.g., **303**AE and **3030**BE) be in the same session. To satisfy the temporal constraint, the start time for S1 (e.g., start time **309**A) is to be before the start time for S2 (e.g., start time **309**B).

When appropriate, end time clipper **311** can output results **314** and/or clipping module **306** can output clipped event **307**.

Method **400** includes an act of determining that state can be cleaned for the first and second event streams up to a specified point in time (act **407**). For example, state cleaning model **332** can determines that can be cleaned from streams **302**A and **302**B up to a specified point in time.

Method **400** includes an act of receiving a current time increment ("CTI") for the second event stream, the CTI for the second event stream indicating that modifications to events prior to the start time of the second event are no longer to occur in the second event stream (act **408**). For example, time finalization module **333** can receive CTI **323** for stream **302**B. CTI **323** indicates that modifications prior to the start time **309**B are no long to occur in event stream **302**B. Method **400** includes an act of determining that the CTI for the second event stream finalizes the second event (act **409**). For example, time finalization module **333** can determine that CTI **323** finalizes event **303**B (and thus also **303**BE).

Method **400** includes an act of receiving a current time increment ("CTI") for the first event stream, the CTI for the first event stream indicating that modifications to events prior to the start time of the second event are no longer to occur in the first event stream (act **410**). For example, time finalization module **333** can receive CTI **322** for stream **302**A. CTI **322** indicates that modifications prior to the start time **309**B are no long to occur in event stream **302**A.

Method **400** includes an act of determining, based on the LASJ predicate, that events from the second event stream prior to the start time of the second event are no longer to interact with events in the first event stream (act **411**). For example, time finalization module **333** can determine, based on LASJ predicate **331**, that events in the stream **302**B prior to start time **309**B are no longer to interact with events in stream **302**A.

Method **400** includes an act of cleaning state for any events prior to the start time of the second event from the first and second event streams in response to determining that state can be cleaned form the first and second event streams (act **412**). For example, state cleaning module **332** can send state cleaning commands **334**. State cleaning commands **334** can indicate that state for any events prior to start time **309**B can be cleaned form streams **302**A and **302**B.

Thus generally, in order for an LASJ operator to clean state, the AlterLifetime for S2 is used to deduce that modifications to S2 are not longer possible. This in turn means that once a CTI(punctuation) is received for S2, which is after some event in S2, that event is finalized, and may be used to delete all entries on S1 which are definitely clipped by that event. Similarly, the LASJ predicate ensures that once a CTI on for S1 has been received, events on S2 whose V_s is less than or equal to the associated timestamp may no longer interact with new events on S1, and may therefore be deleted and used to clean the S1 join synopsis as specified above.

Clipping events can be used for other applications. For example, ClipEventDuraiton can be used to convert a series of point events into a continuous signal, i.e., a series of gapless, non-overlapping interval events. The point events' lifetimes can be extended, so that they reach up to the next event. That is, a timeout is applied that determines how long an event is to maximally last until the next event occurs. The timeout can be a finite time span, such as, for example, 60 seconds, or infinite time span. For example:

var extended=input.AlterEventDuration (e=>TimeSpan.FromSeconds(60));

A ClipEventDuration operator can then be used providing the stream itself as its parameter. As such, each event can be clipped to the next one in the same stream, creating a continuous series of interval events. Since start times of the second stream are used for the clipping operation, the original point stream can be used as the parameter: For example:

var signal=extended.ClipEventDuration(input, (e1, e2)=>true);

FIG. **5** illustrates a graph **500** of events representing point to signal conversion. As depicted in graph **500**, input events **501** are extended into extended input events **503**. The start of each extended input event **502** is used to clip the preceding event resulting in clipped input events **503** (a continuous signal).

Another use for a ClipEventDuration operator is the creation of session events in order to annotate events that occurred during such a session. Consider the following example event schema, describing events of some user interaction:

```
public class EventType
{
    public int UserId;
    public string Type;
    public DateTime Time;
    public byte[ ] data;
};
```

In this example, the payload field Type can be either "start", "end", or "other", describing the start of a user session, the end of a session, or user events during a session, respectively. The field Time contains the timestamp of the interaction, and data contains further information. This data can be used to annotate each event with the start time of the session during which the event occurred.

A duration expansion according to the timeout can be applied to all events of type "start":

```
var sessionStarts = from e in input
    where e.Type == "start"
    select e;
var sessionStartsExt = sessionStarts.
AlterEventDuration(e =>
        TimeSpan.FromMinutes(10));
```

The session events are clipped until their respective end, for each user Id:

```
var sessionEnds = from e in input
where e.Type == "end"
select e;
var sessions = sessionStartsExt.
ClipEventDuration(sessionEnds, (e1, e2) =>
    e1.UserId == e2.UserId);
```

FIG. **6**A illustrates a graph **600** of events representing creation of session events. As depicted, session activity includes start event **602** and end event **603**. Extended start event **602**E is extended to infinity. The start time of end event **603** is used to clip Extended start event **602**E resulting in session **604**.

Session events can then be joined to the remaining events:

```
var sessionActivity = from e in input
        where e.Type == "other"
        select e;
var annotated = from s1 in sessions
    join s2 in sessionActivity
    on s1.UserId equals s2.UserId
    select new {
        s2.UserId,
        s2.Type,
        s2.Time,
        s2.Data,
        SessionStart = s1.Time
    }
```

In the join, sessionActivity events are referred ti as well as the fields of the session event. As such, the annotated sessionActivity event can be assembled, pulling in the session start time to each sessionActivity event.

Since the join condition is the equality of UserId, event **606** with UserId=Y in sessionActivity is not taken into account for this specific session with UserId=X.

FIG. **6**B illustrates graph **600** of events representing annotating session events with other events. As depicted, other events **604** and **607** are annotated to session **604**, as depicted by annotations **611**.

Accordingly, embodiments of the invention include using operators in an event-processing framework (algebra) to shorten (or "clip") the duration of events. An operator can receive a primary event stream, a clip event stream, and condition as parameters. The operator clips the lifetime of an event in the primary stream to the next event in the clip stream that fulfills the condition.

The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed:

1. At a computer system including one or more processors and system memory, the computer system also including stream processing module, the stream processing module configured to process events from a plurality of event streams, a method for adjusting the lifetime of an event in one event stream based on an event in another event stream, the method comprising:

receiving a first event from a first event stream, the first event having a time stamp indicating a start time and end time of the first event, the time from the start time to the end time representing the lifetime of the first event, the first event stream included in the plurality of event streams;

altering the end time for the first event to extend the lifetime of the first event by a specified period of time;

receiving a second event from a second event stream, the second event having a time stamp indicating a start time of the second event, the second event stream included in the plurality of event streams;

determining whether there is a correspondence between the first event and the second event based on a defined join condition, wherein the join condition comprises a temporal restriction which excludes a correspondence between the first event and the second event when the second event is entirely after the first event;

clipping the lifetime of the first event by modifying the first event to end at the start time of the second event in response to the defined join condition indicating a correspondence between the first event and the second event and determining that the start time of the second event is after the start time of the first event; and

determining that state can be cleaned for the first and second event streams up to a specified point in time, including:

receiving a current time increment ("CTI") for the second event stream, the CTI for the second event stream indicating that modifications to events prior to the start time of the second event are no longer to occur in the second event stream;

determining that the CTI for the second event stream finalizes the second event;

receiving a current time increment ("CTI") for the first event stream, the CTI for the first event stream indicating that modifications to events prior to the start time of the second event are no longer to occur in the first event stream;

determining that events from the second event stream prior to the start time of the second event are no longer to interact with events in the first event stream; and

cleaning state for any events prior to the start time of the second event from the first and second event streams in response to determining that state can be cleaned from the first and second event streams.

2. The method as recited in claim **1**, wherein receiving a first event from a first event stream comprises receiving a point event from the first event stream, the point event having a start time and stop time that are the same time.

3. The method as recited in claim **2**, wherein altering the end time for the first event to extend the lifetime of the first event by a specified period of time comprises altering the end time for the point event to extend the lifetime of the point event by the specified period of time.

4. The method as recited in claim **1**, wherein altering the end time for the first event to extend the lifetime of the first event by a specified period of time comprises altering the end time for the first event to extend the lifetime of the first event by a finite period of time.

5. The method as recited in claim **1**, wherein altering the end time for the first event to extend the lifetime of the first event by a specified period of time comprises altering the end time for the first event to extend the lifetime of the first event by a infinite period of time.

6. The method as recited in claim **1**, wherein determining whether there is a correspondence between the first event and the second event comprises determining that the first event is a start event and the second event is an end event corresponding to the same session.

7. The method as recited in claim **6**, where clipping the lifetime of the first event by modifying the first event to end at the start time of the second event comprises clipping the start event to end at the start time of the end event to create a session event.

8. The method as recited in claim **1**, wherein the first event stream and the second event stream are the same specified event stream and wherein clipping the lifetime of the first event by modifying the first event to end at the start time of the second event comprises clipping a first event in the specified event stream with a second event in the specified event stream to generate a continuous signal.

9. A computer program product for use at a computer system including one or more processors and system memory, the computer system also including stream processing module, the stream processing module configured to process events from a plurality of event streams, the computer program product for implementing a method for adjusting the lifetime of an event in one event stream based on an event in another event stream, the computer program product comprising one or more non-transitory computer storage devices having stored thereon computer-executable instructions that, when executed at a processor, cause the computer system to perform the method including the following:

receive a first event from a first event stream, the first event having a time stamp indicating a start time and end time of the first event, the time from the start time to the end time representing the lifetime of the first event, the first event stream included in the plurality of event streams;

alter the end time for the first event to extend the lifetime of the first event by a specified period of time;

receive a second event from a second event stream, the second event having a time stamp indicating a start time of the second event, the second event stream included in the plurality of event streams;

determine whether there is a correspondence between the first event and the second event based on a defined join condition, wherein the join condition comprises a temporal restriction which excludes a correspondence between the first event and the second event when the second event is entirely after the first event;

clip the lifetime of the first event by modifying the first event to end at the start time of the second event in response to the defined join condition indicating a correspondence between the first event and the second event; wherein receiving the second event from the second event stream comprises receiving the second event, wherein the start time of the second event is after the start time of the first event; and

determining that state can be cleaned for the first and second event streams up to a specified point in time, including:

receiving a current time increment ("CTI") for the second event stream, the CTI for the second event stream indicating that modifications to events prior to the start time of the second event are no longer to occur in the second event stream;

determining that the CTI for the second event stream finalizes the second event;

receiving a current time increment ("CTI") for the first event stream, the CTI for the first event stream indicating that modifications to events prior to the start time of the second event are no longer to occur in the first event stream;

determining that events from the second event stream prior to the start time of the second event are no longer to interact with events in the first event stream; and

cleaning state for any events prior to the start time of the second event from the first and second event streams in response to determining that state can be cleaned form the first and second event streams.

10. The computer program product as recited in claim **9**, wherein computer-executable instructions that, when executed, cause the computer system to receive a first event from a first event stream comprise computer-executable instructions that, when executed, cause the computer system to receive a point event from the first event stream, the point event having a start time and stop time that are the same time.

11. The computer program product as recited in claim **10**, wherein computer-executable instructions that, when executed, cause the computer system to altering the end time for the first event to extend the lifetime of the first event by a specified period of time comprise computer-executable instructions that, when executed, cause the computer system to alter the end time for the point event to extend the lifetime of the point event by the specified period of time.

12. The computer program product as recited in claim **9**, wherein computer-executable instructions that, when executed, cause the computer system to alter the end time for the first event to extend the lifetime of the first event by a specified period of time comprise computer-executable instructions that, when executed, cause the computer system to alter the end time for the first event to extend the lifetime of the first event by a finite period of time.

13. The computer program product as recited in claim **9**, wherein computer-executable instructions that, when executed, cause the computer system to alter the end time for the first event to extend the lifetime of the first event by a specified period of time comprise computer-executable instructions that, when executed, cause the computer system to alter the end time for the first event to extend the lifetime of the first event by a infinite period of time.

14. The computer program product as recited in claim **9**, wherein computer-executable instructions that, when executed, cause the computer system to determine whether there is a correspondence between the first event and the second event comprise computer-executable instructions that, when executed, cause the computer system to determine

that the first event is a start event and the second event is an end event corresponding to the same session.

15. The computer program product as recited in claim **9**, wherein the first event stream and the second event stream are the same specified event stream and wherein computer-executable instructions that, when executed, cause the computer system to clip the lifetime of the first event by modifying the first event to end at the start time of the second event comprise computer-executable instructions that, when executed, cause the computer system to clipping a first event in the specified event stream with a second event in the specified event stream to generate a continuous signal.

16. At a computer system including one or more processors and system memory, the computer system also including stream processing module, the stream processing module configured to process events from a plurality of event streams, a method for cleaning state from event streams, the method comprising:

receiving an first event from a first event stream, the first event having a time stamp indicating a start time of the first event, the first event stream included in the plurality of event streams;

extending the lifetime of the first event for a specified period of time such that the first event starts at the start time of the first event and ends at the specified period of time after the start time of the first event;

receiving a second event from a second event stream, the second event having a time stamp indicating a start time for the second event, the second event stream included in the plurality of event streams;

clipping the lifetime of the first event by modifying the first event to end at the start time for the second event, including:

extending the lifetime of the second event for an infinite time period; and

determining that the first event and second event satisfy a join condition and that determines the start time for the second event is after the start time for the first event;

and determining that state can be cleaned for the first and second event streams up to a specified point in time, including:

receiving a current time increment ("CTI") for the second event stream, the CTI for the second event stream indicating that modifications to events prior to the start time of the second event are no longer to occur in the second event stream;

determining that the CTI for the second event stream finalizes the second event;

receiving a current time increment ("CTI") for the first event stream, the CTI for the first event stream indicating that modifications to events prior to the start time of the second event are no longer to occur in the first event stream;

determining that events from the second event stream prior to the start time of the second event are no longer to interact with events in the first event stream; and

cleaning state for any events prior to the start time of the second event from the first and second event streams in response to determining that state can be cleaned from the first and second event streams.

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